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(54) Optical data recording/reproducing method and apparatus

(57) The present invention provides an optical data recording/reproducing method wherein a data is recorded for testing in a pattern consisting of a not-recorded section and a recorded section as changing a recording power P onto an optical data recording medium from time to time, an amplitude m of the recorded data corresponding to the recording power P is monitored by reproducing the data recorded for testing, a standardized gradation g(P) is calculated from the following expression:

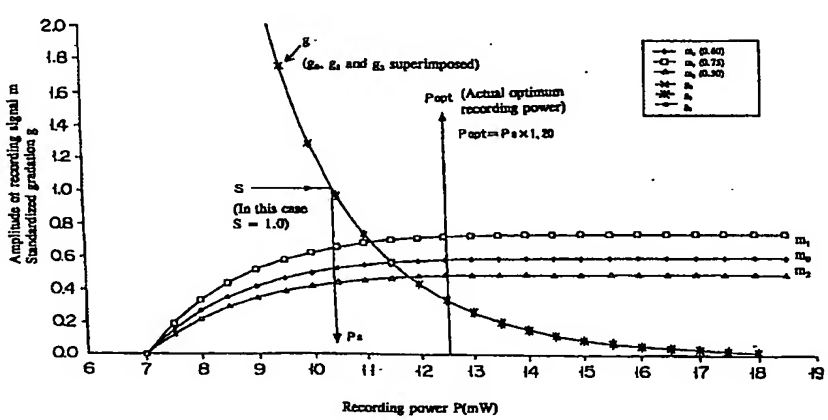
$$g(P)=(\Delta m/m)/(\Delta P/P)$$

or h(P) is calculated from the following expression:

$$h(P)=(\Delta m/m)/\Delta P$$

wherein ΔP indicates a minute change rate near P and Δm indicates a minute change rate corresponding to ΔP near m, and an optimum recording power is decided and set by evaluating excess or shortage of the recording power according to said standardized gradation g(P) or h(P).

FIGURE 4



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Description

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to an optical data recording/reproducing method and apparatus.

DISCUSSION OF THE BACKGROUND

There has been known a method for recording data signals in an optical data recording medium for use in an optical data recording/reproducing apparatus by irradiating a light spot such as a laser beam onto an optical data recording medium for scanning and modulating amplitude of a light spot such as a laser beam with data signals as described in Japanese Patent Publication No. 29336/1988, and also there has been a method for adjusting recording conditions such as a recording power or a recording light pulse to optimum ones by way of reproducing data signals recorded in an optical data recording medium and monitoring an amplitude of the reproduced signals or a length of recording marks.

With any of the technologies as described above, as a matter of fact it is impossible due to the reasons as described below to always set optimum conditions even though data signals is actually recorded using an optical data recording/reproducing apparatus produced in mass.

Namely, as an example of the method described above, the method can be enumerated in which an optimum recording power is set to each optical data recording/reproducing apparatus by monitoring an amplitude of recording signal (a difference between a level of a signal from a not-recorded section and that of a signal from a recorded section) ,which is a representative reproduced signal in an optical data recording medium, but an amplitude value of a recording signal changes according not only to a recording power, but also to a number of openings in an optical pickup, rim intensity (distribution of intensity of an incident laser beam to a focusing lens) ,a size and a form of each light spot, and contamination of the optical system associated with passage of time, and generally offset by 20 to 40% is generated between each optical pickup, so that a set value is largely displaced from the optimum one because of the effect by the offset described above.

So in an optical data recording/reproducing apparatus designed for mass production, it is extremely difficult to set an optimum recording power with a precision acceptable in actual use (around ± 5%). Also there is nonuniformity between individual optical data recording/reproducing apparatus that an amplitude of recording signal for the same recording power can not be a constant level, and in this case, minute adjustment of a recording power is required for each optical data recording/reproducing apparatus. There is a problem in production of the optical data recording/reproducing apparatus.

Moreover, especially, in a repeatedly rewritable optical data recording medium, a test recording is executed in a data track and then an optimum recording power is set. After that, the test data can be erased and a new data can be recorded, or a new data can be overwritten directly in the track in which the test recording is executed. So, though a data track exclusive for testing need not be formed as the postscript type optical data recording medium, it is not prevented that the recording power of the test recording is excessively increased and the data track is damaged. Therefore, as a matter of fact, the data track exclusive for testing need be formed, and there are disadvantages that a setting error of an optimum recording power is enlarged due to a difference of recording characteristic which is due to a position difference of each data track, or the data track exclusive for testing is in vain for a user.

SUMMARY AND OBJECT OF THE INVENTION

Accordingly, one object of the present invention is to provide an optical data recording/reproducing method and apparatus which can set an optimum recording power without an effect of offset of a recording power and/or an amplitude of recording signal.

Another object of the present invention is to provide an optical data recording/reproducing method and apparatus which can easily set an optimum recording power with a precision acceptable in actual use in an optical data recording/reproducing apparatus designed for mass production.

These and other objects and advantages are achieved by the present invention which provides an optical data recording/reproducing method wherein a data is recorded for testing in a pattern consisting of a not-recorded section and a recorded section as changing a recording power P onto an optical data recording medium from time to time, an amplitude m of the recorded data corresponding to the recording power P is monitored by reproducing the data recorded for testing, a standardized gradation g(P) is calculated from the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

or h(P) is calculated from the following expression:

$$h(P)=(\Delta m/m)/\Delta P$$

wherein ΔP indicates a minute change rate near P and Δm indicates a minute change rate corresponding to ΔP near m, and an optimum recording power is decided and set by evaluating excess or shortage of the recording power according to said standardized gradation g(P) or h(P).

BRIEF DESCRIPTION OF THE DRAWINGS

In describing preferred embodiment of the present invention illustrated in the drawings, specified terminology is employed for the sake of clarity. However, the invention is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents which operate in a similar purpose.

A more complete appreciation of the present invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description, particularly when considered in connection with the accompanying drawings, wherein:

Figure 1 is a block diagram showing an optical data recording/reproducing apparatus of embodiments of the present invention;
Figure 2 shows examples of a recording light pulse used in the optical data recording/reproducing apparatus of embodiments of the present invention;
Figure 3 shows an example of effects in embodiments of the present invention; and
Figure 4 shows an example of effects in embodiments of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now Figures, embodiments will be described.

In these embodiments, a rewritable optical disk, optical card or optical tape etc. can be cited as an optical data recording medium which can be used in the present invention , and the present invention can apply to an optical data recording/reproducing method and apparatus which executes hole opening recording or thermal change recording onto pigment, metal or alloy film, magneto-optic recording, phase change recording which changes reflection ratio or phase of light, or etc.

Moreover, in these embodiments, as an irradiation method of a recording light, a proper method for a recording medium and a recording signal can be used, for instance an irradiation method of long and short rectangular pulse lights or that of intermittence of short pulse light which is already known. Figure 2 shows examples of a recording light pulse used in the optical data recording/reproducing apparatus of the embodiments. Figure 2(a) shows an example of a data which intend to be recorded and recording sections 1 and 3, and not-recording section 2 are recorded onto a data track in the optical data recording medium.

The data recorded onto this optical data recording medium is reproduced, and as shown in Figure 2(e) a difference between a signal level from the recording section and a signal level from the not-recording section, that is an amplitude of recording signal, is detected. This amplitude of the recording signal can be generated by a difference reflection ratio between the recording section and the not-recording section in the optical data recording medium or a difference of intensity of a light to which Kerr revolution angle is converted by an optical process in magneto-optic recording.

Figure 2(b), Figure 2(c) and Figure 2(d) show representative examples of a recording light pulse which is applied to the present invention. The example in Figure 2(b) is most simple one where modulation is executed by corresponding a weak reproducing power Pr and a strong recording power Pw to the not-recording section and the recording section. It is suitable for recording a data onto a recording surface of low heat conduction. The example in Figure 2(c) is that a long recording section is recorded by a pulse train and it is suitable for recording a data onto a recording surface of high heat conduction by a constant recording width.

The example in Figure 2(d) is one of recording pulses that records a data onto a recording surface where overwriting is possible in magneto-optic recording or phase change recording. In a data track where a data is already recorded, a light of an erasing power Pe of middle level is continuously irradiated and therefore a not-recording section is formed. A recording power P and a bias power Pb are irradiated by turns and therefore an old data is erased and a new data is replaced.

Next, a description is made for logical background of the embodiment of the invention. When amplitude m_0 of a standard recording signal monitored by a standard data recording/reproducing apparatus and a standard recording power P_0 are given through the following expression:

$$m_0=m_0(P_0).$$

a ratio $g_0(P_0)$ obtained by furthermore standardizing Δm_0 and ΔP_0 corresponding to m_0 and P_0 respectively by m_0 and P_0 is expressed by the following expression as a function of P_0

$$g_0(P_0)=(\Delta m_0/m_0)(\Delta P_0/P_0).$$

Herein $g_0(P_0)$ indicates a standardized gradation of m_0 against P_0, so that is called " standardized gradation"

An advantage of using this "standardized gradation" consists in the point that it is applicable also to a relation between an amplitude m of a general recording signal and a general recording power P with each offset from the respective standard which are given by the following expression:

$$m(P)=km_0(P),\ P=qP_0$$

k, q: Constants which are not zero. As clearly understood from the following expressions:

$$\begin{aligned}g(P)&=(\Delta m/m)/(\Delta P/P)\\&=\{\Delta(km_0)/(km_0)\}/\{\Delta(qP_0)/(qP_0)\}\\&=(\Delta m_0/m_0)/(\Delta P_0/P_0)=g(P_0).\end{aligned}$$

so far as the standardized gradation g(P) is monitored, always a value equal to the standard value $g_0(P_0)$ can be obtained.

In other words, a value of g(P) is a numerical value stored irrespective of whether m and P are offset or not, and for this reason it may be said that the numerical value always and accurately indicates whether a recording power is excessive or short. Accordingly, by setting a recording power P for recording data so that the standardized gradation value g(P) will be obtained in the data recording/reproducing apparatus, even if data is recorded with a different data recording/reproducing apparatus, always data can be recorded in the same recording conditions, which is quite convenient for applications in the industrial fields where importance is put on reproductivity of recorded data.

Naturally as a value of a recording power becomes larger, a value of m is saturated and generally g (P) is converged to zero, and for this reason to more accurately detect whether a recording power is excessive or short, it is efficient to set a value of g(P) in a range from 0.2 to 2.0, more preferably in a range from 0.7 to 1.7 and get an optimum recording power by multiplying a value of P corresponding to this by a value in a range from 1.0 to 1.7, preferably in a range from 1.0 to 1.5.

Next, a description is made for a concrete method of obtaining a standardized gradation g.

The general expression for calculating a standardized gradation g is as follows:

$$g(P)=(\Delta m/m)(\Delta P/P)$$

wherein ΔP is a minute change rate near P, and Δm indicates a minute change rate corresponding to ΔP near m.

A practical expression for calculating a standardized gradation when recording powers for i-th and (i+t)-th test recording are P(i) and P(i+1) respectively, and amplitudes of recording signal are m(i) and m(i+1) respectively, is as follows:

$$g[(P(i)+P(i+1))/2]=[\{(m(i+1)-m(i)\}/\{m(i+1)+m(i)\}]/[\{P(i+1)-P(i)\}/\{P(i+1)+P(i)\}].$$

Other practical expression for computing a standardized gradation g is, when recording powers for (i-l)th, i-th, and (i+1)th test recording are P(i-1), P(i) and P(i+1) respectively, and amplitudes of recording signal are m(i-1) ,m(i) ,and m(i+1) respectively, and at the same time when $P(i)=\{P(i+1)+P(i-1)\}/2$, is as follows :

$$g(i)=[\{m(i+1)-m(i-1)\}/\{(m(i+1)+m(i-1)\}]\ /[\{P(i+1)-P(i-1)\}/\{(P(i+1)+P(i-1)\}].$$

Figure 1 is a block diagram showing an optical data recording/reproducing apparatus of embodiments of the present invention. In this embodiment, an optical data recording medium 11 such as an optical disk is driven by a driving device 12 such as a spindle motor. An optical source such as a semiconductor laser is driven by a laser driving circuit 14 of an optical source driving device and irradiates a light onto the optical data recording medium 11 by way of an optical system not shown in the figure, and therefore a recording/reproducing pickup 13 records and reproduces a data.

A recording power setting circuit 15 of a recording power setting device is controlled by a recording controlling block 16 of a recording controlling device which controls overall controlling system and it sets a recording power for testing

and an optimum recording power. Namely the recording controlling block 16 sets the recording power for testing and the optimum recording power through the recording power setting circuit 15, the laser driving circuit 14 and the recording/reproducing pickup 13. The laser driving circuit 14 drives the semiconductor laser to emit at the recording power for testing or the optimum recording power which is set by the recording power setting circuit 15.

During a recording power setting mode, the laser driving circuit 14 drives the laser in the recording/reproducing pickup 13 to emit at the recording power for testing P set by the recording power setting circuit 15, which changes from time to time. Also the recording/reproducing pickup 13 records a pattern of a not-recording section and a recording section onto the optical data recording medium 11 for the recording for testing as changing the recording power P from time to time and reproduces the data of the pattern therefrom.

A monitoring circuit of amplitude of recording signal 17 which is a monitoring device of amplitude of recording signal monitors an amplitude m of recording signal corresponding to the recording power P, which is a difference between a signal level of the not-recording section and that of the recording section, from a reproducing signal which is reproduced by the recording/reproducing pickup 13. A standardized gradation calculating circuit 18 of a calculating device seeks by the recording power P, the amplitude m of recording signal monitored in the monitoring circuit of amplitude of recording signal 17 and by the following expression:

$$g(P)=(\Delta m/m)(\Delta P/P)$$

wherein ΔP is a minute change rate near P, and Δm indicates a minute change rate corresponding to ΔP near m.

The recording controlling block 16 decides the optimum recording power on the basis of the standardized gradation g(P) calculated by the standardized gradation calculating circuit 18, and sets the optimum recording power in the recording power setting circuit 15.

During a recording mode, the laser driving circuit 14 drives the laser in the recording/reproducing pickup 13 to emit at the optimum recording power set by the recording power setting circuit 15 and the recording/reproducing pickup 13 records a data onto the optical data recording medium 11 at the optimum recording power. During a reproducing mode, the laser driving circuit 14 drives the laser in the recording/reproducing pickup 13 to emit at a reproducing power and the recording/reproducing pickup 13 reproduces the data from the optical data recording medium 11 by a light of the reproducing power.

Fig. 3 shows an example of effects provided in this embodiment of the invention. Relations between amplitude m of recording signal recorded and reproduced by different 3 types of data recording/reproducing apparatus and the recording power P are as shown in Fig. 3, and a saturation value of amplitude of recording signal in each case is different: 0.60, 0.75, and 0.50 respectively, so that different curves m(0) , m (1) and m (2) are provided, and in this case an uniform target of optimum recording power can not be obtained even with reference to a certain amplitude level of recording signal, and nonuniformity is generated in response to the curves m(0) ,m(1) and m(2). Furthermore if P is larger than 12 mW (P > 12 mW) ,the three curves m(0), m(1) and m(2) are almost parallel to each other, so that it is impossible even to set a common reference for amplitude level of recording signal.

As for the relation between a standardized gradation g and a recording power P in the embodiment of the invention, the curves g(0), g(l), and g(2) obtained by computing through the expression for definition above are completely coincided from each other. For this reason, in the recording control block 16, if a recording power Pset which gives a determined level, for instance $g(g_{set})=0.25$, by using the curve for the standardized gradation g, even if data recording/reproducing apparatuses used are different, an unified recording power Pset can be set without nonuniformity. In other words, this indicates excellent effects provided in the embodiment of the invention, and also indicates that the versatility and precision in recording power setting are very high.

In this embodiment, it is possible to accurately set an optimum recording power by recording a data for testing in an optical data recording medium in which a data can be recorded, and also it is possible to record a data in an erasable optical data recording medium without giving damages to a recording film by irradiating an excessive recording power, and furthermore it is possible to make lagers the times of erasing and also to improve the reliability of recorded data. In addition, there occurs no nonuniformity such as different amplitude levels of recording signal even if an identical recording power is used for various types of optical data recording/reproducing apparatuses, an optimum recording power can automatically be set without being affected by nonuniformity between various types of data recording/reproducing apparatus, and a low cost optical data recording/reproducing apparatus can be provided.

As described above, in the data recording/reproducing method of the embodiment of the invention, a data is recorded for testing in patterns each consisting of a not-recorded section and a recorded section as changing a recording power P from time to time to the data recording medium, the data recorded for testing is reproduced and an amplitude m of recording signal corresponding to a recording power P is monitored, a standardized gradation g (P) is obtained through the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

wherein ΔP is a minute change rate near P and Δm is a minute change rate corresponding to ΔP near m; and an optimum recording power is decided and set by checking whether a recording power is excessive or short according to the standardized gradation g(P), so that an optimum recording power can be set without an effect of both offsets of an amplitude m of recording signal and a recording power P which occur easily in plural optical data recording/reproducing apparatuses and especially it is easy to set an optimum recording power with a precision acceptable in actual use in an optical data recording/reproducing apparatus designed for mass production.

Moreover, another embodiment will be described. In the data recording/reproducing apparatus of this embodiment, a recording/reproducing pickup 13 which records/reproduces a data for testing in patterns each consisting of a not-recorded section and a recorded section as changing a recording power P from time to time to/from the optical data recording medium 11, a laser driving circuit 14 of an optical source which drives the optical source in this recording/reproducing pickup 13, a recording power setting circuit 15 of a recording power setting device which sets a recording power for testing and an optimum recording power in the recording/reproducing pickup 13, a monitoring circuit 17 of amplitude of recording signal of a monitoring device of amplitude of recording signal which monitors an amplitude m of recording power corresponding to the recording power from the recording/reproducing pickup 13, a standardized calculating circuit 18 of a calculating device which seeks a standardized gradation g (P) by the recording power P for testing, the amplitude m of recording signal and the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

wherein ΔP is a minute change rate near P and Δm is a minute change rate corresponding to ΔP near m; and a recording controlling block 16 of a recording controlling device which decides an optimum recording power by checking whether a recording power is excessive or short according to the standardized gradation g(P) sought in the standardized calculating circuit 18 and sets it to the recording power setting circuit 15 are included, so that an optimum recording power can be set without an effect of both offsets of the amplitude m of recording signal and the recording power P which occur easily in plural optical data recording/reproducing apparatuses and especially it is easy to set an optimum recording power with a precision acceptable in actual use in an optical data recording/reproducing apparatus designed for mass production.

In the embodiment as described above, the recording controlling block 16 detects a recording power Ps at which the standardized gradation g(P) coincides with the a specific value S which is selected in a range from 0.2 to 2.0, and it sets an optimum recording power to the recording power setting circuit 15 by multiplying Ps by a value in a range from 1.0 to 1.7.

Fig. 4 shows an example of effects provided in the embodiment of the invention. In this embodiment, a relation between an amplitude m of recording signal and a recording power P and a relation between a standardized gradation g and a recording power P are the same as those in the embodiment of the above invention. In the embodiment of the invention, when setting an optimum recording power, in a range of P > 13 mW where the amplitude m of record signal is saturated to a recording power, a value of the standardized gradation g itself becomes smaller, and also a change rate to P becomes smaller, so that it is easily affected by external disturbance or noise and a precision in detection of P may become lower. In other words, it is better for improving a precision in detection of P to use a condition where a value of g is large and a change rate to P is also large (where a gradation is large).

Fig. 4 shows an example of effects provided in the embodiment of the present invention in which S of the specific value is 1.0, and also this figure shows an effect provided by the method of detecting a recording power Ps at which a value of the standardized gradation g coincides with S in this embodiment. Ps is smaller than an actual optimum recording power Popt, so that Popt is set by multiplying this Ps by 1.20. The particular value of S may be selected from a range from 0.2 to 2.0 so that influence by noise will be negligible, and in this case it is possible to detect a recording power Ps corresponding to a set value S with high precision. Offset of a recording power Ps from the optimum recording power Popt can be checked by previously setting an appropriate value in a range from 1.0 to 1.7 times and by computing the optimum recording power Popt by multiplying Ps by this value. For this reason an optimum recording power can furthermore precisely be set.

As described above, in the embodiment, a data is recorded for testing in patterns each consisting of a not-recorded section and a recorded section changing a recording power P from time to time to the data recording medium, the data recorded for testing is reproduced and an amplitude m of recording signal corresponding to a recording power P is monitored, a standardized gradation g(P) is obtained through the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

wherein ΔP is a minute change rate near P and Δm is a minute change rate corresponding to ΔP near m; a specific value S selected from a range from 0.2 to 2.0 is set, a recording power Ps at which the standardized gradation g(P) coincides with the value of S is detected, and an optimum recording power is set by multiplying Ps by a value in a range from 1.0 to 1.7, so that it is possible to furthermore precisely set an optimum recording power and also to reduce a cost

of a data recording/reproducing apparatus.

Furthermore, another embodiment will be described. In this embodiment, an optical data recording medium is repeatedly rewritable and recording for testing is executed under the condition that g(P) is 0.15 or more and a track for testing in the optical data recording medium is included within data tracks. As a result, a track exclusive for testing, which is unnecessary for a user, can be omitted, and also setting precision of the optimum recording power can be improved.

Generally, it has been confirmed experimentally that the recording power does not damage all kinds of optical data recording media thermally if the g(P) is 0.15 or more. Therefore in this embodiment, excessive recording power does not irradiate onto a recording film of the optical data recording medium, so that the recording film is not damaged. Thus a track for testing is unnecessary to be formed, and even if recording for testing is executed on a data track where a data is recorded, there occurs no problem. Therefore it is achieved that the setting precision of the optimum recording power can be improved.

Concretely, the recording for testing is executed as changing the recording power upward on a data track which is first one circle of the data tracks and then a data for testing is reproduced from the track where the recording for testing is executed. At that time, if g(P) reaches around 0.15, the recording for testing is stopped. Then the optimum recording power is decided under the condition that g(P) is 0.15 or more as described above. A data starts to be overwritten from the beginning of the first track where the recording for testing is executed. Generally, a recording characteristic is almost same among tracks around the track where the test recording is executed. Thus, over tracks whose length is once to several hundreds times as long as the length of the track where the recording for testing is executed, or otherwise over whole tracks, a data is recorded in a good condition.

As described above, in this embodiment, the optical data recording medium is repeatedly rewritable and recording for testing is executed under the condition that g(P) is 0.15 or more and the track for testing in the optical data recording medium is included within data tracks. As a result, the track exclusive for testing, which is unnecessary for a user, can be omitted, and also setting precision of the optimum recording power can be improved.

In addition, in the embodiment described above, under the condition that the offset of the recording power is small enough, the offset of the amplitude of recording signal can be reduced by using $h(P)=(\Delta m/m)/\Delta P$ instead of $g(P)=(\Delta m/m)/(\Delta P/P)$, and therefore those embodiments of the invention include the case of $h(P)=(\Delta m/m)/\Delta P$ instead of $g(P)=(\Delta m/m)/(\Delta P/P)$. In this case, with respect to the specific value S which is selected from 0.2 to 2.0, a first specific value is used as so that the amplitude of recording signal does not saturate to the recording power, and with respect to the value of 1.0 to 1.7, a second specific value is properly used.

Furthermore, another embodiment will be described. In this embodiment, in one portion of an optical data recording medium, a recommendation value of at least one of the value of the recording power, g(P), h(P) and the ratio between the optimum recording power and Ps etc., which are for seeking the optimum recording power by the recording for testing, is prerecorded previously.

Generally, the recording power, g(P), h(P) and the ratio between the optimum recording power and Ps etc., which are for seeking the optimum recording power by the recording for testing, have a recommendation value respectively depending on a material of a recording film or structure of the optical data recording medium. Therefore if each recommendation value is pre-recorded previously in the one portion of the optical data recording medium as inherent data and it is reproduced in the optical data recording/reproducing apparatus, the optimum recording power per the optical data recording/reproducing apparatus can be sought precisely by the recording for testing. As examples of the recommendation value, it is preferable that they can be reproduced by the recording/reproducing pickup, for instance, known ones such as modulated pre-pit array, recorded pit array or modulation pattern of bar coding are possible.

As a result, the optimum recording power per the optical data recording medium can be precisely sought by the recording for testing. Therefore the optical data recording media of many companies where the recording characteristic are different can be used widely and so called interchangebility among the optical data recording media can be improved.

As described above, in this embodiment, in one portion of the optical data recording medium, the recommendation value of at least one of the value of the recording power, g(P), h(P) and the ratio between the optimum recording power and Ps etc., which is for seeking the optimum recording power by the recording for testing, are pre-recorded previously. Therefore the optimum recording power per the optical data recording medium can be precisely sought by the recording for testing. Therefore the optical data recording media of many companies where the recording characteristic are different can be used widely and the interchangebility among the optical data recording media can be improved.

Finally, the technical advantages will be described.

According to an optical data recording/reproducing method of the present invention, a data is recorded for testing in patterns each consisting of a not-recorded section and a recorded section as changing a recording power P from time to time to the data recording medium, the data recorded for testing is reproduced and an amplitude m of recording signal corresponding to a recording power P is monitored, a standardized gradation g (P) is obtained through the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

or h(P) is obtained through the following expression:

$$h(P)=(\Delta m/m)/\Delta P$$

wherein ΔP is a minute change rate near P and Δm is a minute change rate corresponding to ΔP near m; and an optimum recording power is decided and set by checking whether a recording power is excessive or short according to the standardized gradation g(P) or h(P), so that an optimum recording power can be set without an effect of both offsets of an amplitude m of recording signal and a recording power P which occur easily in plural optical data recording/reproducing apparatuses and especially it is easy to set an optimum recording power with a precision acceptable in actual use in an optical data recording/reproducing apparatus designed for mass production.

According to an optical data recording/reproducing method of the present invention, a data is recorded for testing in patterns each consisting of a not-recorded section and a recorded section changing a recording power P from time to time to the data recording medium, the data recorded for testing is reproduced and an amplitude m of recording signal corresponding to a recording power P is monitored, a standardized gradation g(P) is obtained through the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

wherein ΔP is a minute change rate near P and Δm is a minute change rate corresponding to ΔP near m; a specific value S selected from a range from 0.2 to 2.0 is set, a recording power Ps at which the standardized gradation g(P) coincides with the value of S is detected, and an optimum recording power is set by multiplying Ps by a value in a range from 1.0 to 1.7, so that it is possible to furthermore precisely set an optimum recording power and also to reduce a cost of a data recording/reproducing apparatus.

According to an optical data recording/reproducing method of the present invention, a data is recorded for testing in patterns each consisting of a not-recorded section and a recorded section changing a recording power P from time to time to the data recording medium, the data recorded for testing is reproduced and an amplitude m of recording signal corresponding to a recording power P is monitored, h(P) is obtained through the following expression:

$$h(P)=(\Delta m/m)/\Delta P$$

wherein ΔP is a minute change rate near P and Δm is a minute change rate corresponding to ΔP near m, a recording power Ps, for which said h(P) is identical to a first specific value which is selected in a range where the amplitude of recording power is not saturated to the recording power, is detected and an optimum recording power is set by multiplying Ps by a second specific value, so that it is possible to furthermore precisely set an optimum recording power and also to reduce a cost of a data recording/reproducing apparatus.

According to an optical data recording/reproducing apparatus of the present invention, a recording/reproducing pickup which records/reproduces a data for testing in patterns each consisting of a not-recorded section and a recorded section as changing a recording power P from time to time to/from the optical data recording medium, a laser driving circuit of an optical source which drives the optical source in this recording/reproducing pickup, a recording power setting circuit of a recording power setting device which sets a recording power for testing and an optimum recording power in the recording/reproducing pickup, a monitoring circuit of amplitude of recording signal of a monitoring device of amplitude of recording signal which monitors an amplitude m of recording power corresponding to the recording power from the recording/reproducing pickup, a standardized calculating circuit of a calculating device which seeks a standardized gradation g (P) or h(P) by the recording power P for testing, the amplitude m of recording signal and the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

or

$$h(P)=(\Delta m/m)/\Delta P$$

wherein ΔP is a minute change rate near P and Δm is a minute change rate corresponding to ΔP near m; and a recording controlling block of a recording controlling device which decides an optimum recording power by checking whether a recording power is excessive or short according to the standardized gradation g(P) or h(P) sought in the standardized calculating circuit and sets it to the recording power setting circuit are included, so that an optimum recording power can be set without an effect of both offsets of the amplitude m of recording signal and the recording power P which occur

easily in plural optical data recording/reproducing apparatuses and especially it is easy to set an optimum recording power with a precision acceptable in actual use in an optical data recording/reproducing apparatus designed for mass production.

According to an optical data recording/reproducing method of the present invention, an optical data recording medium is repeatedly rewritable and recording for testing is executed under the condition that g(P) is 0.15 or more and a track for testing in the optical data recording medium is included within data tracks. As a result, a track exclusive for testing, which is unnecessary for a user, can be omitted, and also setting precision of the optimum recording power can be improved.

According to an optical data recording/reproducing method of the present invention, in one portion of the optical data recording medium, the recommendation value of at least one of the value of the recording power, g(P), h(P) and the ratio between the optimum recording power and Ps etc., which is for seeking the optimum recording power by the recording for testing, are pre-recorded previously as inherent data. Therefore the optimum recording power per the optical data recording medium can be precisely sought by the recording for testing. Therefore the optical data recording media of many companies where the recording characteristic are different can be used widely and the interchangebility among the optical data recording media can be improved.

The optimum recording power may additionally or alternatively be determined by analyzing the saturation behaviour of the function m(P). This analyzing may be done by means of a function g(P) which may be obtained by means of approximation methods from the individual g(P) values (e.g. by a fitted curve). This function may then be extrapolated to obtain the saturation value for the amplitude. Alternatively the saturation value for the amplitude may be obtained from the value of P for certain value of g, e.g. for g = 0,15, and by multiplying the corresponding value for the amplitude m by a constant factor.

Alternatively a fuzzy logic may be implemented in order to find both a sufficiently large value of g and a sufficiently large change rate to P.

Furthermore the values for g(P) may be analyzed statistically in order to determine if the section of the recording medium used to determine g(P) is damaged. This may be assumed if a large scattering of the calculated values for g(P) may be observed. If this is the case a warning may be signaled. Furthermore tracks may be determined which may not be used for data recording. This may be done by skipping all tracks for recording between two testing sections (i.e. sections used to determine g(P) values) which provided an error free result, if between this two testing section one or more testing sections have been observed which provide a result indicating a damage. This allows for using a recording medium even if a part of the recording medium is damaged. Due to the standardization of the gradation g(P) reliable threshold values for indicating a damage may be determined, even if various types of recording mediums are used.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims the invention may be practiced otherwise than as specifically described herein.

Claims

1. An optical data recording/reproducing method, wherein a data is recorded for testing in a pattern consisting of a not-recorded section and a recorded section as changing a recording power P onto an optical data recording medium from time to time, an amplitude m of the recorded data corresponding to the recording power P is monitored by reproducing the data recorded for testing; a standardized gradation g(P) is calculated from the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

or h(P) is calculated from the following expression:

$$h(P)=(\Delta m/m)/\Delta P$$

wherein ΔP indicates a minute change rate near P and Δm indicates a minute change rate corresponding to ΔP near m; and an optimum recording power is decided and set by evaluating excess or shortage of the recording power according to said standardized gradation g(P) or h(P).

2. An optical data recording/reproducing method according to claim 1, wherein a specific value S selected in a range from 0.2 to 2.0 is set; a recording power Ps, for which said standardized gradation g(P) is identical to S, is detected; and an optimum recording power is set by multiplying Ps by a value in a range from 1.0 to 1.7.

3. An optical data recording/reproducing method according to claim 1, wherein a recording power Ps, for which said h(P) is identical to a first specific value which is selected in a range where said amplitude of the recorded data is

not saturated to said recording power, is detected; and an optimum recording power is set by multiplying Ps by a second specific value.

4. An optical data recording medium driving apparatus using an optical data recording medium, comprising:

a recording/reproducing pickup (13) which records a data for testing in patterns each consisting of a not-recorded section and a recorded section as changing a recording power P from time to time to the optical data recording medium (11) and reproduces the data therefrom;
an optical source driving device (14) which drives an optical source in the recording/reproducing pickup (13);
a recording power setting device (15) which sets the recording power P for testing and an optimum recording power to the recording/reproducing pick-up;
a monitoring device (17) of amplitude of recording signal which monitors an amplitude m of recorded data corresponding to the recording power P from the recording/reproducing pickup;
a calculating device (18) which calculates a standardized gradation g(P) or h(P) by the recording power P for testing, the amplitude m of the recorded data and the following expression:

$$g(P)=(\Delta m/m)/(\Delta P/P)$$

or

$$h(P)=(\Delta m/m)/\Delta P$$

wherein ΔP is a minute change rate near P and Δm is a minute change rate corresponding to ΔP near m; and

a recording controlling device (16) which decides the optimum recording power by evaluating excess or shortage of the recording power according to the standardized gradation g(P) or h(P) calcuated in the calculating device and sets the optimum recording power to the recording power setting device.

5. An optical data recording/reproducing method according to claim 1, 2 or 3, wherein an optical data recording medium used in the optical data recording/reproducing method is a repeatedly rewritable data recording medium, a track which is recorded for testing is included within data tracks on which a data intends to be recorded by the optimum recording power set by the testing and the recording power P for testing is changed under a condition that a value of g(P) is 0.15 or more.

6. An optical data recording/reproducing method according to claim 1, 2, 3 or 5, wherein, in one portion of an optical data recording medium used in the optical data recording/reproducing method, a recommendation value of at least one of the recording power, g(P), h(P) or a ratio between the optimum recording power and Ps for calculating the optimum recording power is previously prerecorded as inherent data.

7. An optical data recording/reproducing method according to claim 1-3, 5 or 6, wherein a saturation value Msat for m(P) is estimated from g(P), e.g. by extrapolation, and the optimum recording power Popt is set such that Popt results in an amplitude Mopt(Popt) which saturates the following equation:

$$0.5\ \mathrm{Msat} < \mathrm{Mopt} < 0.99 \cdot \mathrm{Msat}.$$

8. An optical data recording/reproducing method according to claims 1-3, 5-7, wherein in $\Delta g(P)/(\Delta P/P)$ is determined, wherein $\Delta g(P)$ is the change of g(P) near P, and the optimum recording power Popt is chosen such that the amount of $\Delta g(Popt)/(\Delta P/Popt)$ is within a predetermined range.

9. An optical data recording/reproducing method according to claim 1-3, 5-8, wherein a statistical data analysis of the values of g(P) is performed in order to determine if the recording section is damaged, in order to signal a damage result by a warning means and/or to skip tracks nearby the section for testing.

10. An optical data recording/reproducing method according to claim 9, wherein a damage is determined if the scattering of the individual g(P) values about a curve fitted to these values, which fitting being obtained e.g. by least mean square methods, is above a certain threshold value.

FIGURE 1

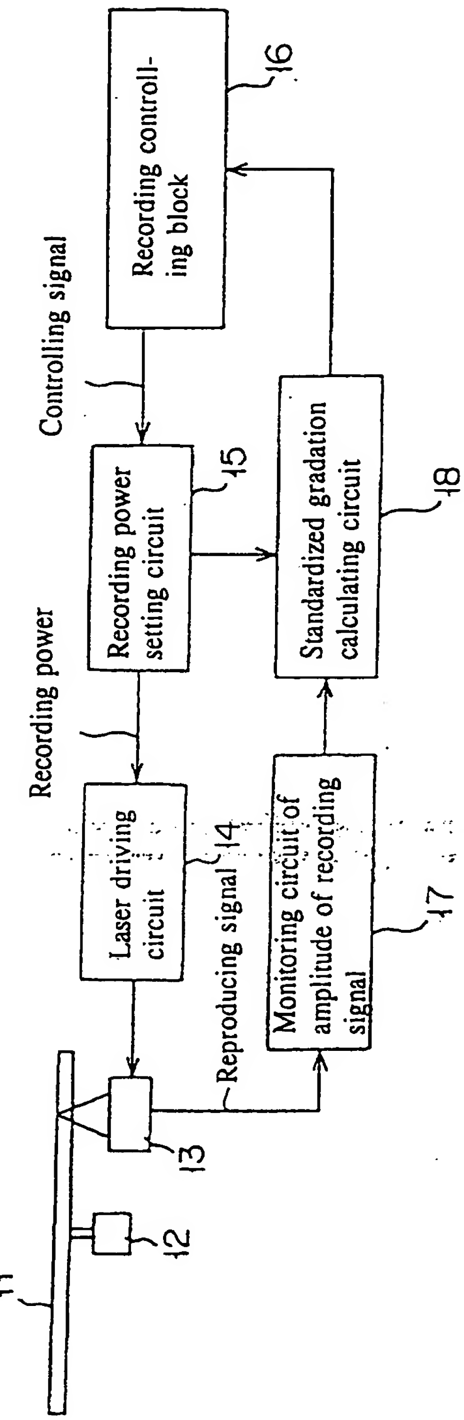

Recording controll-
ing block
16
Controlling signal
Recording power
setting circuit
15
Standardized gradation
calculating circuit
18
Recording power
Laser driving
circuit
14
Monitoring circuit of
amplitude of recording
signal
17
Reproducing signal
13
12
11

FIGURE 2

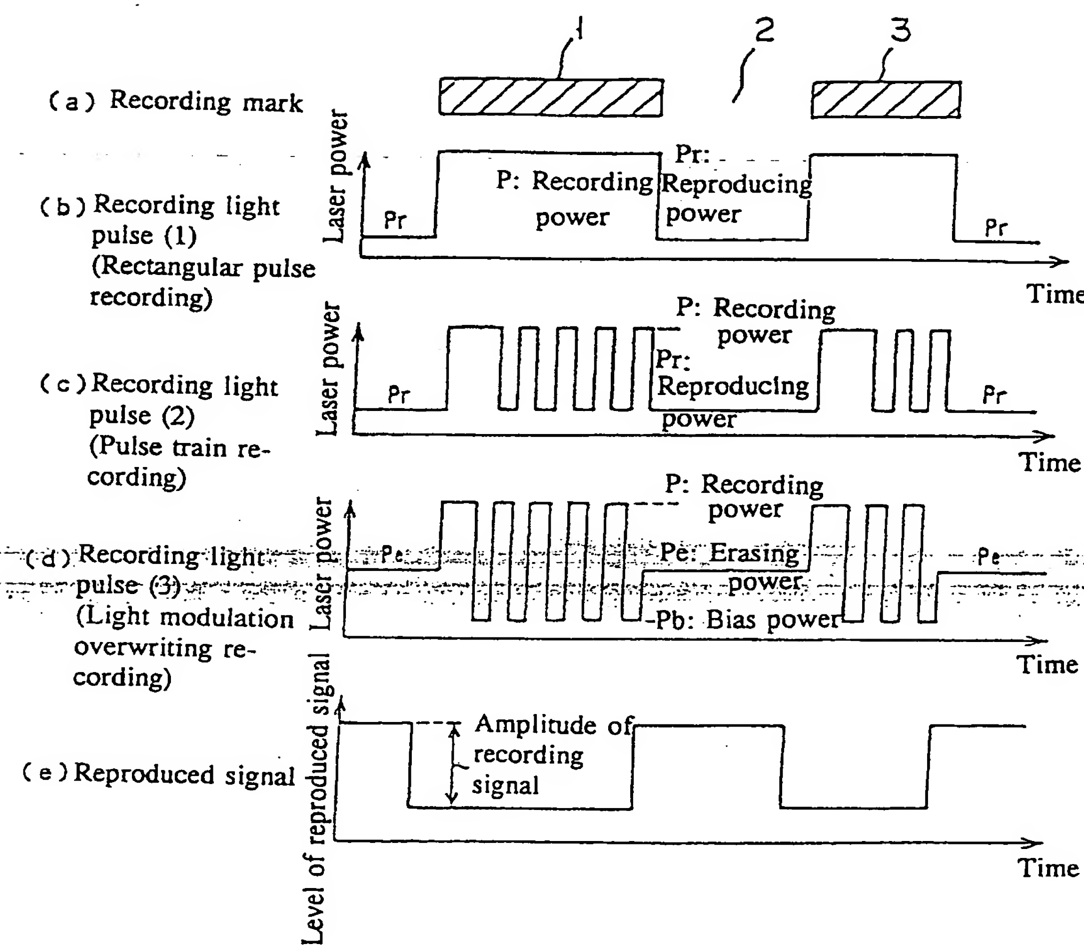

1
2
3
(a) Recording mark
(b) Recording light pulse (1) (Rectangular pulse recording)
Laser power
Pr
P: Recording power
Pr: Reproducing power
Pr
Time
(c) Recording light pulse (2) (Pulse train recording)
Laser power
Pr
P: Recording power
Pr: Reproducing power
Pr
Time
(d) Recording light pulse (3) (Light modulation overwriting recording)
Laser power
Pe
P: Recording power
Pe: Erasing power
Pb: Bias power
Pe
Time
(e) Reproduced signal
Level of reproduced signal
Amplitude of recording signal
Time

FIGURE 3

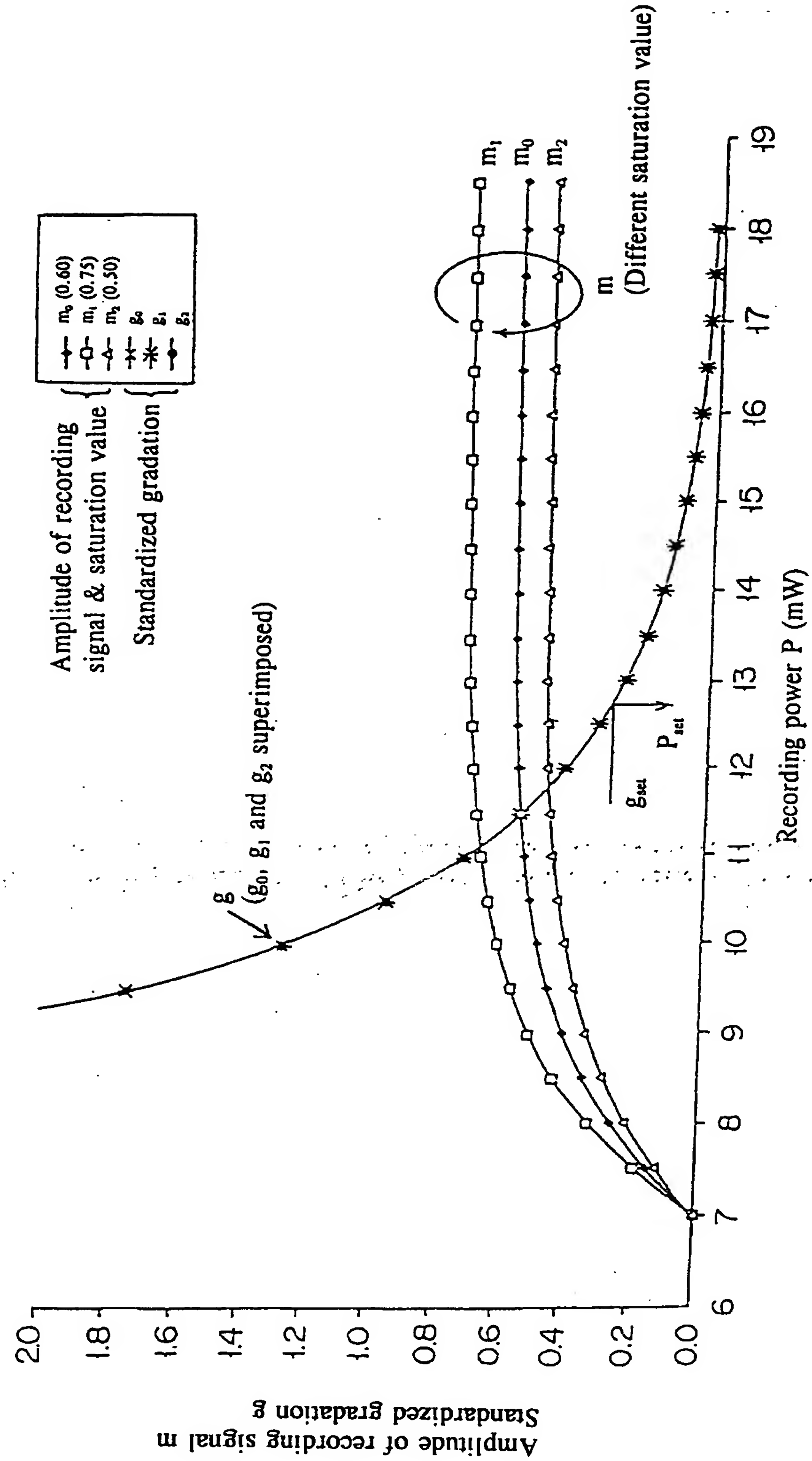
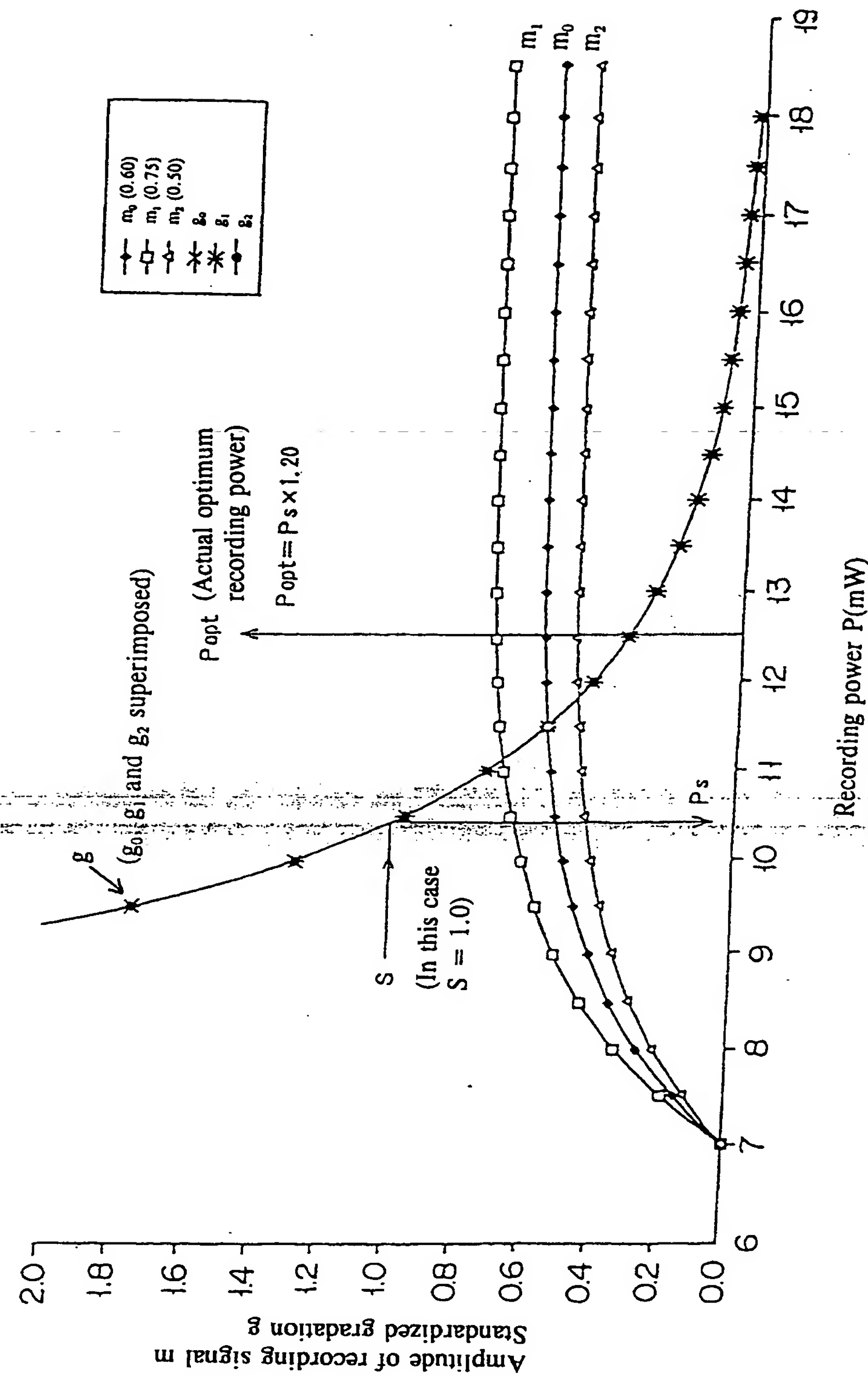

Amplitude of recording signal & saturation value
Standardized gradation
m0 (0.60)
m1 (0.75)
m2 (0.50)
g0
g1
g2
g (g0, g1 and g2 superimposed)
m1
m0
m2
m (Different saturation value)
gset
Pset
Recording power P (mW)
Amplitude of recording signal m
Standardized gradation g
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
6
7
8
9
10
11
12
13
14
15
16
17
18
19

FIGURE 4



m_0 (0.60)
m_1 (0.75)
m_2 (0.50)
g_0
g_1
g_2
m_1
m_0
m_2
g
(g_0, g_1 and g_2 superimposed)
Popt (Actual optimum recording power)
Popt = Ps × 1.20
Ps
S
(In this case S = 1.0)
Recording power P(mW)
Amplitude of recording signal m
Standardized gradation g
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
6
7
8
9
10
11
12
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16
17
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19

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 4553

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	WO-A-93 26001 (MAXOPTIX CORP) 23 December 1993 * page 1, paragraph 2 * * page 11, paragraph 2 - page 12, paragraph 3 * * page 16, paragraph 1 - page 17, paragraph 2; claims 9,28; figures 2,3 * ---	1,4,5,9	G11B7/125
A	US-A-4 283 785 (MIYAUCHI TOSHIMITSU ET AL) 11 August 1981 * column 3, line 17 - column 4, line 26; figures 4,5 * ---	1-4	
A	US-A-5 268 893 (CALL DAVID E ET AL) 7 December 1993 * abstract * * column 4, line 58 - column 5, line 35; figure 1 * ---	1,4,5	
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 665 (P-1844), 15 December 1994 & JP-A-06 259769 (RICOH CO LTD), 16 September 1994, * abstract * ---	1,4	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G11B
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 618 (P-1831), 24 November 1994 & JP-A-06 231463 (MATSUSHITA ELECTRIC IND CO LTD), 19 August 1994, * abstract * ---	1,4	
A	EP-A-0 587 111 (PIONEER ELECTRONIC CORP) 16 March 1994 * abstract * -----	1,4,9	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 December 1996	Annibal, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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